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**BUREAU OF MINES
R. R. SAYERS, ACTING DIRECTOR**

INFORMATION CIRCULAR

CUTTING AND POLISHING STONES



BY

M. W. VON BERNEWITZ AND FRANK HESS

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

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By M. W. von Bernewitz^{2/} and Frank Hess^{3/}

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PURPOSE OF THIS REPORT

Because the cutting and polishing of stones are parts of the work of the Bureau of Mines in its study of rocks and minerals and in the determination of specimens sent in for identification, it was decided that a circular covering the subject in a general way would be of practical interest. As several books and periodicals give details of the problems in cutting and polishing, this report will not duplicate their information more than necessary.

ACKNOWLEDGMENT

The manuscript for this circular was read by Oliver Bowles and Forrest Moyer, Building Materials unit, Bureau of Mines, who supplied some of the illustrations; several photographs were taken by Howard Carl, Optical Section, Bureau of Mines. Equipment firms that contributed information and publishing houses whose books have been abstracted are mentioned in the text.

EXTENT OF THE STONE INDUSTRY

Of the 1,766,120 tons (approximately 22,430,000 cubic feet) of dimension stone, exclusive of slate, valued at \$21,778,000, produced in the United States during 1938 as building stone and monumental stone, granite sold or used amounted to 3,059,950 cubic feet; marble, 1,045,680 cubic feet; limestone, 5,077,950 cubic feet; and sandstone, 332,530 cubic feet (the average for all stones is 12.7 cubic feet to 1 short ton), according to Bureau of Mines Minerals Yearbook, 1939, which reviews operations in 1938. These quantities are somewhat lower than in 1937, as were those for slate, according to Oliver Bowles and M. Schauble's chapters "Stone" and "Slate". The finished slate millstock amounted to 3,575,220 square feet, equivalent approximately to 16,310 short tons and valued at \$853,602. Millstock includes electrical slate, structural and sanitary slate, grave vaults and covers, blackboards and bulletin boards, billiards-table tops, and school slates.

The cutting and polishing of building stones and monumental stones - limestone, marble, sandstone, granite, basalt and related rocks, and rocks of special quality - constitute a national industry employing many men working in numerous well-equipped mills.

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- 1/ The Bureau of Mines will welcome reprinting of this report, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7107."
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CHARACTERISTICS OF ROCKS AND STONES

A short section on the characteristics of several common rocks is in order at this point. Rocks may be defined as the geologic formations of hard, naturally occurring substances formed of one or more varieties of minerals in place in the earth, and stones as individual blocks or fragments broken away from rock formations, naturally or by applied force.

Limestone and Marble

Limestone is the general name for a sedimentary rock composed essentially of calcium carbonate. Marble is crystallized limestone, this change having taken place under pressure and heat. Limestone is used unpolished for structural purposes, and marble commonly is polished for building and decorative uses. Although variable, limestone has a gravity of approximately 2.7 and a hardness of 3 and is normally whitish to grayish, but varies considerably in color. It is composed mainly of calcium carbonate, with varying quantities of magnesium carbonate, and some clay, silica, and iron oxide. When the magnesium carbonate content approaches 5 percent the rock is termed dolomite.

Sandstone

Sandstone is a sedimentary rock formed of cemented quartz sand. Although very variable, its gravity is approximately 2.6 and hardness 6; but this depends on the degree of concentration, and the extreme is 7, the hardness of the quartz grains. It is cut and used unpolished in structural work. Some sandstones have high moisture content when first quarried or excavated and may be cut with an ax or hand saw, but when they become hard and resist weathering. Sydney, Australia, is built upon rock of this type. On the other hand, the stone used at Stanford University, California, is so porous that it would freeze to pieces in the Northern States, and the popular brown stone is so nonporous that it is suitable for the climate of the Northern States.

Slate

Slate is a finely granular, crystalline rock, generally derived from clay or shale beds that have been subjected to great pressure, that has developed its characteristic property of cleaving along smooth planes, which allow the rock to be split easily. Slate may be of several colors, the most common being dark gray. Although variable, its gravity is approximately 2.7 and hardness 5.

Basalt

Basalt and other dark, basic, finely crystalline igneous rocks known as trap rocks occur as lavas, dikes, or sills. The lavas and dikes are known as diabase because the degree of crystallization is generally

different. Basalts have a gravity of 2.75 to 2.99 and a hardness of 5 to 6. Generally, they are used unpolished, but some types are polished and used as memorial or decorative stone. Some ancient statues of basalt have been cut and polished.

Granite

Granite is a granular igneous rock composed mainly of quartz, feldspar and mica, which minerals may be identified easily on examination. The gravity of granite is 2.6 to 3.30 and the hardness is approximately 7. Granite is used for all types of construction, including monuments--polished and unpolished.

Quartz

Quartz, which consists of silicon dioxide crystallized with more or less impurities, has a gravity of 2.6 and a hardness of 7. It is the most common and versatile mineral, and its varieties include agate, rock crystal, jasper, amethyst, and opal, to name a few forms.

Boulders

Boulders, according to Bowles, are "rolling stones" and originally were masses of rock loosened from the parent deposit by natural processes and moved long or short distances by glaciers, streams, or other natural forces. Thus they became rounded. Boulders often are used as they occur, in homes, clubhouses, and walls or farm fences. For the first two purposes, cobbles commonly are used, and may be classed as rubble or rough building stone; but in glaciated regions, in Victoria, Australia, and in other places, boulders of various granitoid rocks weighing several hundred pounds each sometimes are used. In New Zealand, where many country fences are built of lava, 5- to 10-ton granite boulders are transported coastwise on scows or barges. These are sawed to size for construction purposes. A peculiar feature of many boulders is that they do not belong to their present place of rest. In Central Park, New York City, which is underlain by gneiss or schist, are granitoid boulders that have been moved by glacial action from northern Canada.

CUTTING ROCKS IN QUARRY

Channeling and Wire-Sawing

Quarrying limestone, marble, and sandstone by channeling, or slate, limestone, and marble by wire-sawing may be considered a cutting operation because both methods give dimension stone a flat face for further dressing. Channeling is a chopping action, whereas wire-sawing is cutting

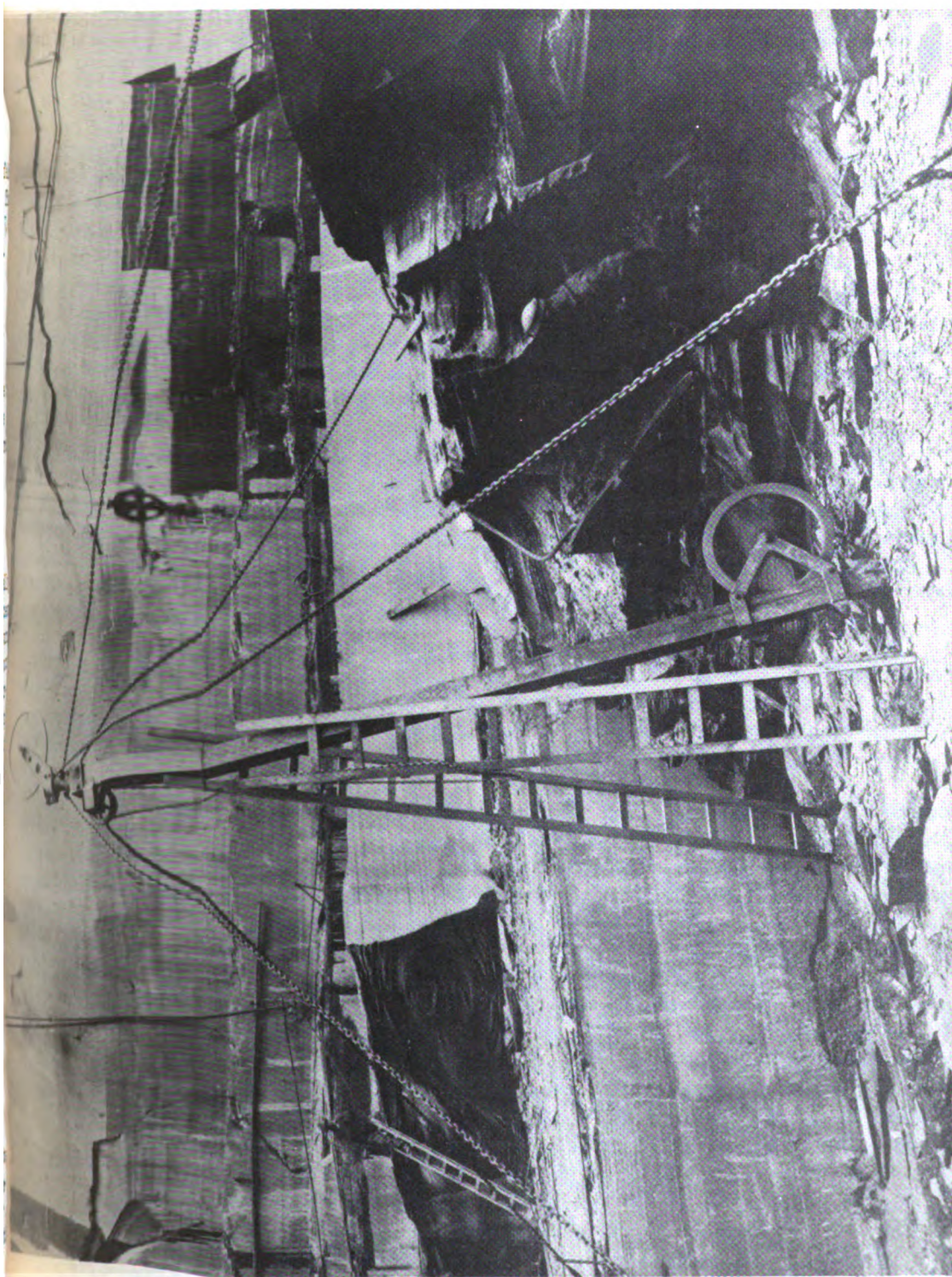


Figure 1.- Wire-saw set-up at a Pennsylvania quarry. Note
smooth cut.

by abrasion. Both methods have been described by Bowles^{4/} and by others, and excerpts are given here. Illustrations of limestone, marble, sandstone, and slate (fig. 1) quarries generally show smooth walls and even-surfaced blocks of stone that are being moved to the finishing mills. Such surfaces lessen the work of subsequent cutting and polishing.

Channeling

Limestone.-- The first step in the process of block removal of limestone is channeling. The channeling machine is mounted on a frame and travels back and forth on a track. Steel bars operating with a chopping action similar to that of a reciprocating drill cut a narrow channel in the rock. Some machines are driven by steam or compressed air, and some by electricity. Channel cuts usually are made about 4 feet apart and 3 to 12 feet deep. The duplex machine, which makes a double cut, averages 200 to 300 square feet of channel per day, and the cost of cutting is 3 to 12 cents per square foot. Common sizes of mill blocks are 10 by 4 by 3 feet and 10 by 4 by 4 feet.

Marble.-- Primary cuts generally are made with channeling machines. A favorite machine is the double-swivel channeler, which may be used for vertical, horizontal, and inclined cuts. Electric air machines are in common use. The rate of channeling varies greatly; recorded averages range from 25 to 80 square feet per day for one machine. The quarry floor may be enlarged by inclining the channel wall cuts outward. This process is known as undercutting.

Sandstone.-- Most of the sandstone produced is of the softer types, which may be cut with channeling machines. As a rule, sandstones so hard that they make good paving blocks are too hard to channel economically, and primary breaks must be made by blasting.

The channeling process is much the same in sandstone as in limestone, except that the quartz grains wear the steel more rapidly. Steel must be changed frequently. Cuts are about 4 inches wide at the top but become narrower with depth because of loss of gage through wear. A stream of water carries away the sand cuttings. Channel cuts are made parallel or at right angles to the major jointing systems. The large masses of sandstone separated by joints or channel cuts may be free at the quarry

^{4/} Bowles, Oliver, The Technology of Marble Quarrying: Bureau of Mines Bull. 106, 1916, pp. 53-71 (channeling); pp. 71-74 (wire-sawing); pp. 94-108 (sawing and polishing). Sandstone Quarrying in the United States: Bureau of Mines Bull. 124, 1917, pp. 39-45 (channeling); pp. 68-75 (sawing and finishing). The Technology of Slate: Bureau of Mines Bull. 213, 1922, pp. 31-33 (channeling); p. 33 (wire-sawing); pp. 74-76 (sawing and finishing). The Wire Saw as a Tool for Cutting Slate and Building Stone: Trans. Am. Inst. Min. and Met. Eng. vol. 129, 1938, pp. 56-61. Dimension Stone: The Seeley W. Mudd Series, A.I.M.E., Industrial Minerals and Rocks, 1937, pp. 775, 780, 787 (channeling and wire-sawing limestone, sandstone, marble, and soapstone); pp. 776-777, (footnotes continued on following page).

floor if bed seams are present. If not, a separation is made by driving wedges in drill holes. The larger masses are subdivided by wedging, supplemented at times by light charges of black blasting powder.

Soapstone.— A stripped quarry floor is channeled across the strike with steam or electric-air machines. After a center row of key blocks has been removed, all other channeled masses are undercut to their full depth. An average block is 4 by 4 by 6 feet.

Wire-Sawing

Slate.— In Europe, the wire saw has been used for many years, but it was not operated extensively in the United States until 1928, when it was generally accepted by the Pennsylvania slate industry. The "saw" is a twisted, three-strand, steel cable of 1/4 or 3/16 inch diameter running a an endless belt (fig. 2). Sand fed upon the wire by water serves as the abrasive. The wire is driven by a motor and is carried into the quarry over several sheaves. It is kept taut by a tension device. Depth is acquired by two holes drilled into the rock by a 36-inch core drill. In these holes are placed standards down which the sheaves that carry the wire are lowered progressively. The method eliminates shattering and reduces waste, which is considerable by other methods. The wire saw cuts rapidly and requires little power or attention. It offers so many advantages that one would expect to find it in much wider use than it is at present.

Limestone.— The high cost of channeling has encouraged operators to experiment with more economical methods, and wire saws have been tested successfully in several limestone quarries.

Marble.— Wire saws have been tried on marble at several places, and some degree of success has been attained in Arkansas, Tennessee, and Vermont. The wire cuts slowly and wears out more rapidly than in slate or limestone.

4/ (Cont.) 781-782, 786-787, 787-788 (sawing and polishing limestone, sandstone, marble, and soapstone.) The Stone Industries: McGraw-Hill Book Co., New York City, 2d ed., 1939, pp. 46-53, 83-84, 208-210, 255-260, 293 (channeling and some wire-sawing limestone, sandstone, marble, slate, and soapstone); pp. 55-58, 92-95, 218-219, 274-276, 293 (sawing and finishing limestone, sandstone, marble, slate, soapstone).

Behre, C. H., Slate: Trans., Am. Inst. Min. and Met. Eng. Industrial Minerals and Rocks, 1937, pp. 732-733 (channeling and wire-sawing) pp. 733-734 (sawing and polishing).

Bain, G. W., Mining Marble: Trans. Am. Inst. Min. and Met. Eng., vol. 129, 1938, pp. 101-106 (channeling and wire-sawing).



**Figure 2.- Wire saw in operation.
Note narrow and smooth cut.**

ABRASIVES FOR SAWING, CUTTING, AND POLISHING

Information on abrasives is scattered, but interested persons will find useful items in publications of the Bureau of Mines^{5/} and National Bureau of Standards^{6/} and in circulars of the firms listed in the former.

Sand

Abrasive sand includes all natural sands used for abrasive and grinding purposes. They are composed of hard grains and, generally speaking, contain a high percentage of silica. They may be used for sawing stone, grinding glass, and sandblasting, and as sandpaper. Those used for different purposes vary somewhat in character. Abrasives made by crushing garnet and emery are being superseded largely by artificial abrasives.

Sand for sawing stone preferably consists of uniform grains; fine material is objectionable. However, unsorted sand is sometimes employed. One large marble company used a clean, washed river sand with 3.7 percent retained on 10 mesh, 12.6 percent on 20 mesh, 83.8 percent on 40 mesh, and 93.6 percent on 100 mesh. The sand may be reused after washing to remove the fines. There are no uniform requirements regarding shape of grain. The sand should be dominantly quartz.

Glass-grinding sand is used for rough-grinding of crude-rolled plate glass. The requirements of the sand are not strict. Fine grains and clay are objectionable. One company employs sand all of which will pass 20-mesh and 20 percent of which is retained on 150-mesh. Banding sand, which is used for second or semifinal grinding of plate glass, is considerably finer than that employed for the first grinding. It is used less than formerly, as it has been replaced to a large extent by artificial abrasives.

Metallic Abrasives

These include crushed steel, steel shot, and angular steel grit. The first is crushed to 2- to 200-mesh. After screening, each batch is heat-treated and separated into 25 sizes ranging from 20- to 200-mesh. Steel shot is made from high-grade materials and blown into small globules while molten. It is graded into 15 sizes of 4- to 90-mesh. Steel grit is the granulated material coarser than 4-mesh derived from the foregoing operation. Seven firms in the United States make metallic abrasives.

^{5/} Johnson, B. L., and Schauble, M., Abrasive Materials: Bureau of Mines Minerals Yearbook, 1939, pp. 1225-1240.

^{6/} National Bureau of Standards, Artificial Abrasives and Abrasive Products: Letter Circ. 540, Dec. 21, 1938, 8 pp.

Artificial Abrasives

Silicon carbide and aluminum oxide are made in electric furnaces by ~~four~~ firms and six firms, respectively, under such brand names as Carborundum and Crystolon and as Aloxite and Alundum. Silicon carbide is extremely hard (up to 9-1/2) but brittle and aluminum oxide is almost as hard (9) and sharp, but much tougher. One firm makes boron carbide, whose hardness is somewhat higher than that of silicon carbide, but we have no information as to the extent to which it is used.

Other Abrasives

For polishing, several oxides - tin oxide, iron oxide, chromium oxide, magnesium oxide, manganese oxide, and lime - are used; also clay, talc, and whiting.

PREPARATION OF STONES FOR MARKET

This section of the circular has been compiled partly from the references (particularly those of Bowles) in the previous section, from recent personal observations, and from information supplies by the following firms: American Saw & Tool Works, Chicago, Ill.; R. C. Atkins & Co., Indianapolis, Ind.; The Carborundum Co., Niagara Falls, N.Y.; Lane Manufacturing Co., Montpelier, Vt.; E. T. Lippert Saw Co., Pittsburgh, Pa.; Musto-Keenan Co., Los Angeles, Calif.; Norton Co., Worcester, Mass.; The Oden Corporation, College Point, N.Y.; Patch-Wegner Co., Rutland, Vt.; J. K. Smit & Sons, Inc., New York City; and Stanley Electric Tool Division, New Britain, Conn.

Equipment Used

Well-furnished finishing mills are equipped for drafting and pattern-making, scabbling, sawing, planing, jointing, milling, turning, fluting, cutting, carving, packing, and shipping. Most limestone fabricated in mills in the quarry districts is furnished on contract for specific jobs, and therefore each block or slab is cut for its particular place. Consequently, the preparation of detailed shop drawings and patterns is an important preliminary step. A drawing of the block showing exact dimensions is consulted at each step in the manufacturing process, also in placing it in a building, a practice the authors have observed in several structures.

Overhead traveling cranes with lifting capacity up to 50 tons handle blocks of stone expeditiously. Heavy powerful cranes are used for large blocks and lighter, more rapidly moving cranes for smaller pieces. It is general practice to use 4-inch canvas, balata, or rubber belt attached to the crane hook instead of chains or wire rope to prevent the chipping of finished edges and corners, which are commonly protected by excelsior or shredded wood.

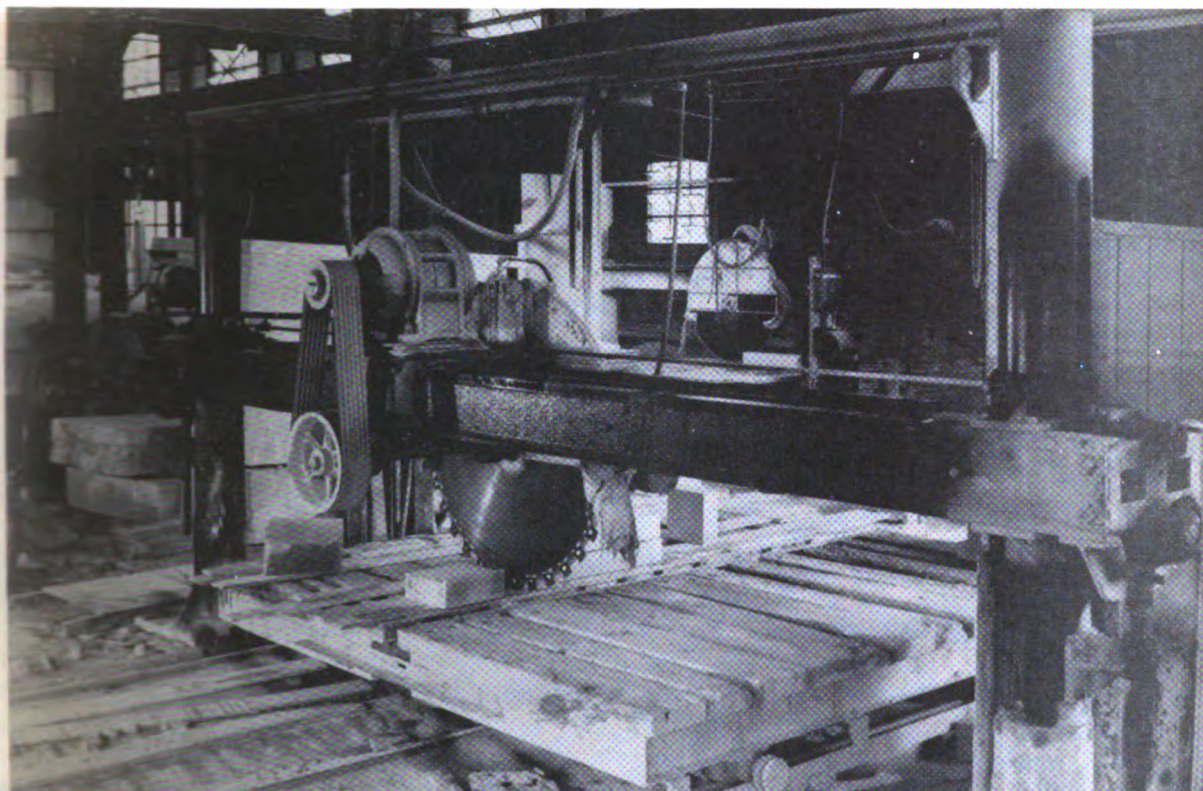


Figure 3.- Five-foot saw with carborundum teeth. Beyond is a 6-foot diamond saw.

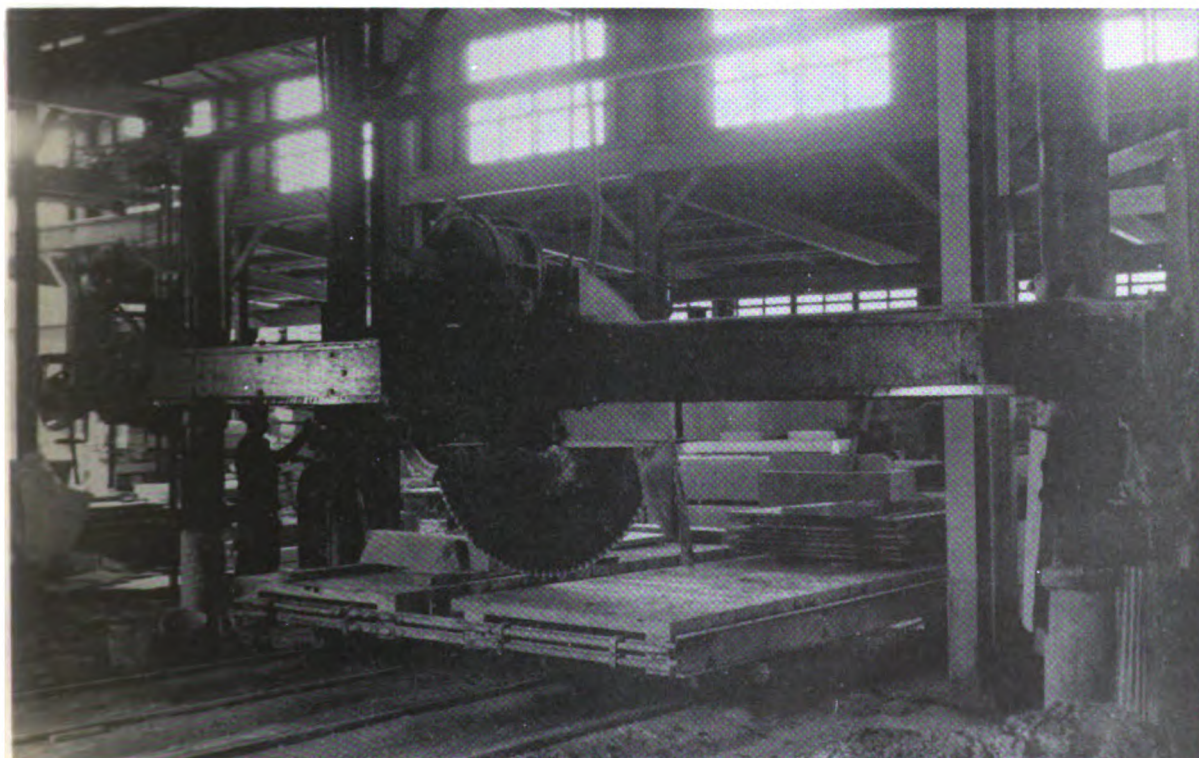


Figure 4.- Six-foot saw with diamond-impregnated teeth.

The term "scabbling," used above, means a process of trimming blocks to a rectangular shape. Various methods of scabbling are employed. Limestone scabbling may be done by hand with a scabbling pick, with circular saws, wire saws, heavy iron disks provided with cutting tools, diamond-toothed drag saws, or scabbling planers. The planers consist of massive blades, which scrape the surface. Such blades will remove 1/4 to 1/2 inch of stone at each cut. Blocks for export trade or for shipment to distant mills are scabbled most carefully. Where blocks are fabricated into finished products in near-by mills, the scabbling step may be omitted.

A useful adjunct to a mill is a wire saw. Several blocks of stone may be placed in line and sawed simultaneously. Sand or crushed steel is used as abrasive. Stone such as marble should be of uniform composition to be adaptable to the wire saw.

Cutting and Finishing Limestone

The first step is to saw rough blocks into slabs. Gang saws like those described later for granite are used generally. They operate with a swinging motion, the blades lifting toward the end of the stroke and permitting the abrasive to wash under them. The abrasives used are sand, "chats" (cherty limestone rock obtained at the Missouri lead and zinc mills), and steel shot. Limestone saws much more rapidly than granite; the blades sink at an average rate of about 6 inches an hour. A straight blade with diamond teeth is used frequently for making single cuts.

Circular diamond saws are used generally for making subsequent cuts. Common sizes are 72 inches with 110 to 125 teeth, 60 inches with 84 diamond teeth, and 36 inches. Each saw is designed for a standard speed and should be run at no other. With care, a saw may be used for 6 months to a year without conditioning. The cutting edge must be cooled constantly with a stream of water. The saw travels at a rate of 3 to 16 inches a minute, depending on the depth of the cut. Recently, in the Phelps Stone Works, Washington, D. C., the authors watched a 72-inch saw at work. It is chain-driven and makes a smooth cut rapidly. This shop also has a 36-inch diamond saw. A 60-inch carborundum saw is also used, and the authors watched this at work on limestone. (Figs. 3 and 4 photographed by Howard Carl of the Bureau of Mines.)

A planer is a machine provided with a cutting tool having lateral and vertical adjustment. As the block of stone is carried beneath it on a traveling bed or platen a thin layer of stone is scraped from the surface. (See fig. 6.) Both sides and tops of blocks may be planed to desired dimensions. Moldings may be cut by using tools of any prescribed pattern. Some planers are adjusted to cut curved forms. A carborundum planer consists of two silicon-carbide saws with a drum of smaller diameter between them. They trim top and sides of the block with one motion.

The O'Meara stone works in Blatimore was visited by one of the authors, and figures 5 and 6 are photographs taken there by Howard Carl. This large plant is a typical stone-working mill and is well-equipped with cutting (gang saws and diamond circular saws) and finishing (planing, polishing, and fluting machines) equipment, as well as with overhead cranes in each bay. There is rail connection. Limestone, marble, and granite are handled. Figure 5 shows a block of Indiana limestone about 116 by 37 by 34 inches just cut into eight 4-inch slabs by nine gang saws using steel shot. This stone is cut at the rate of 8 inches per hour; the rate in granite is 3 inches. The shot is circulated, being picked up by a belt-and bucket elevator at the left side and fed to the saws from the rotary distributor above. The blades are 12 feet long and have a 2-foot stroke. They are made from 8-inch steel 1/4 inch thick, and "teeth" are cut every 15 inches by means of an oxyacetylene torch. Figure 6 shows one of the slabs being planed. The tool is 8 inches wide and is making a finishing cut 1/16 inch deep.

Building limestone is sold with various types of surface finish. A tooled surface has fine parallel grooves. A four-cut surface is made with a planer tool having four corrugations to the inch. A bush-hammered surface is rough and pitted. A shot-sawed or ripple surface is deeply scored by using steel-shot abrasive with gang saws. Chat-sawed surface is somewhat smoother than shot-sawed.

Slabs or blocks of limestone 1 to 2 inches thick and several feet square and other forms sometimes are smoothed with sand by being held atop a gear-driven, central-spindle, cast-iron table or rubbing bed 13 feet in diameter rotating at 40 revolutions per minute as in the Phelps shop.

Cutting and Finishing Marble

Gang saws like those used in limestone mills are in general use. Marble saws slowly. In stone of moderate hardness the blades may sink at a rate of 1 inch to 2 inches an hour; in the harder, siliceous marbles they may sink not more than 3 or 4 inches during an entire shift. Some large marble mills are equipped with more than 40 gang saws. (Figs. 7, 8, and 9.)

Circular saws ranging from 24 to 72 inches in diameter and fitted with silicon carbide teeth are said to cut as rapidly as diamond saws and are more economical generally. A small-tooth saw is used for cutting soft marble.

Slabs or blocks may be squared and finished on rubbing beds like those mentioned. Irregular surfaces are rubbed by hand with abrasive bricks or with pieces of marble supplied with sand and water.

"Gritting," a process that gives a smoother surface than rubbing, usually is accomplished with abrasive bricks attached to revolving buffer heads. The bricks may be of silicon carbide or aluminum oxide.

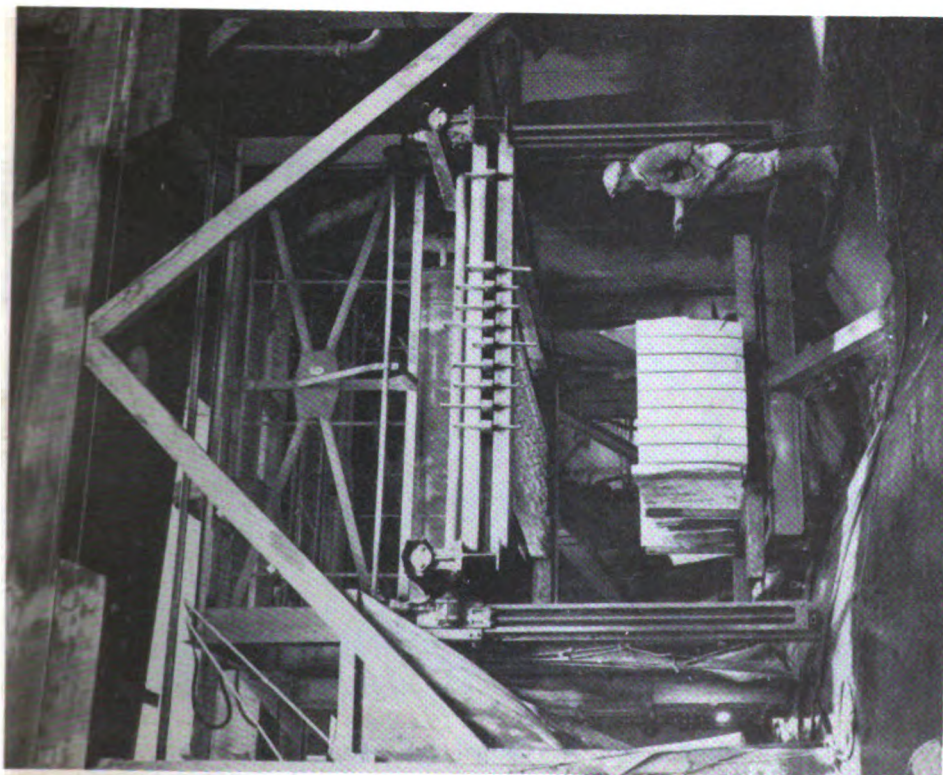


Figure 5.— Limestone cut by gang saws.

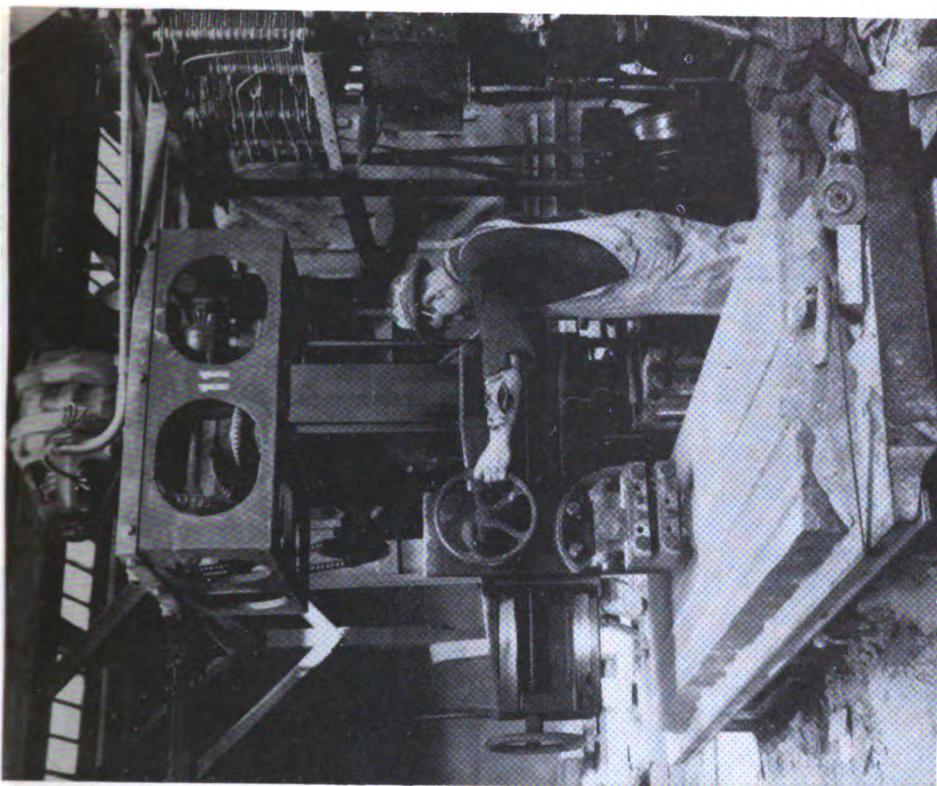


Figure 6.— Planing limestone slab.

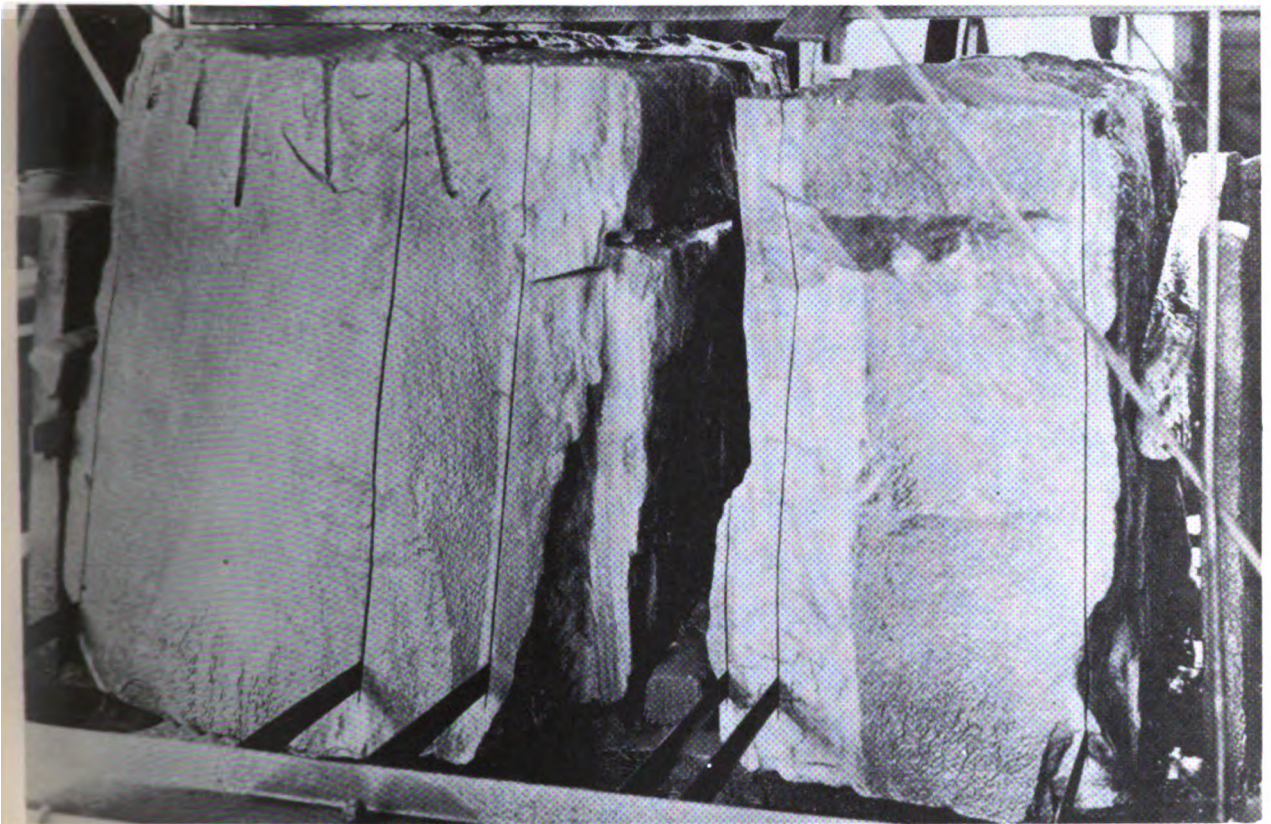


Figure 7.— Gang saws in a Vermont marble shop.

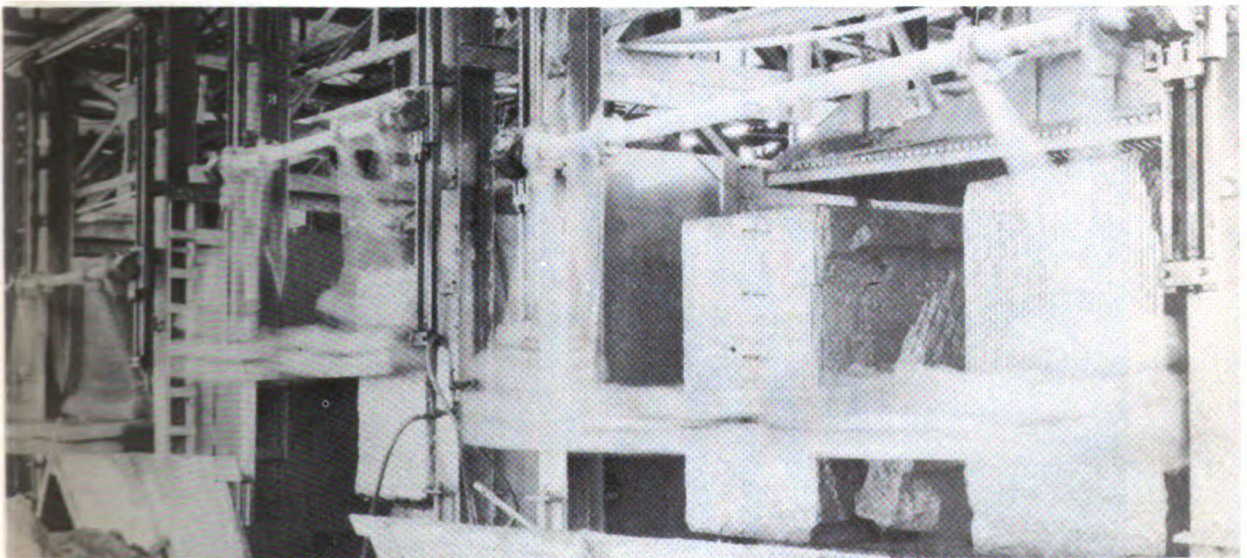
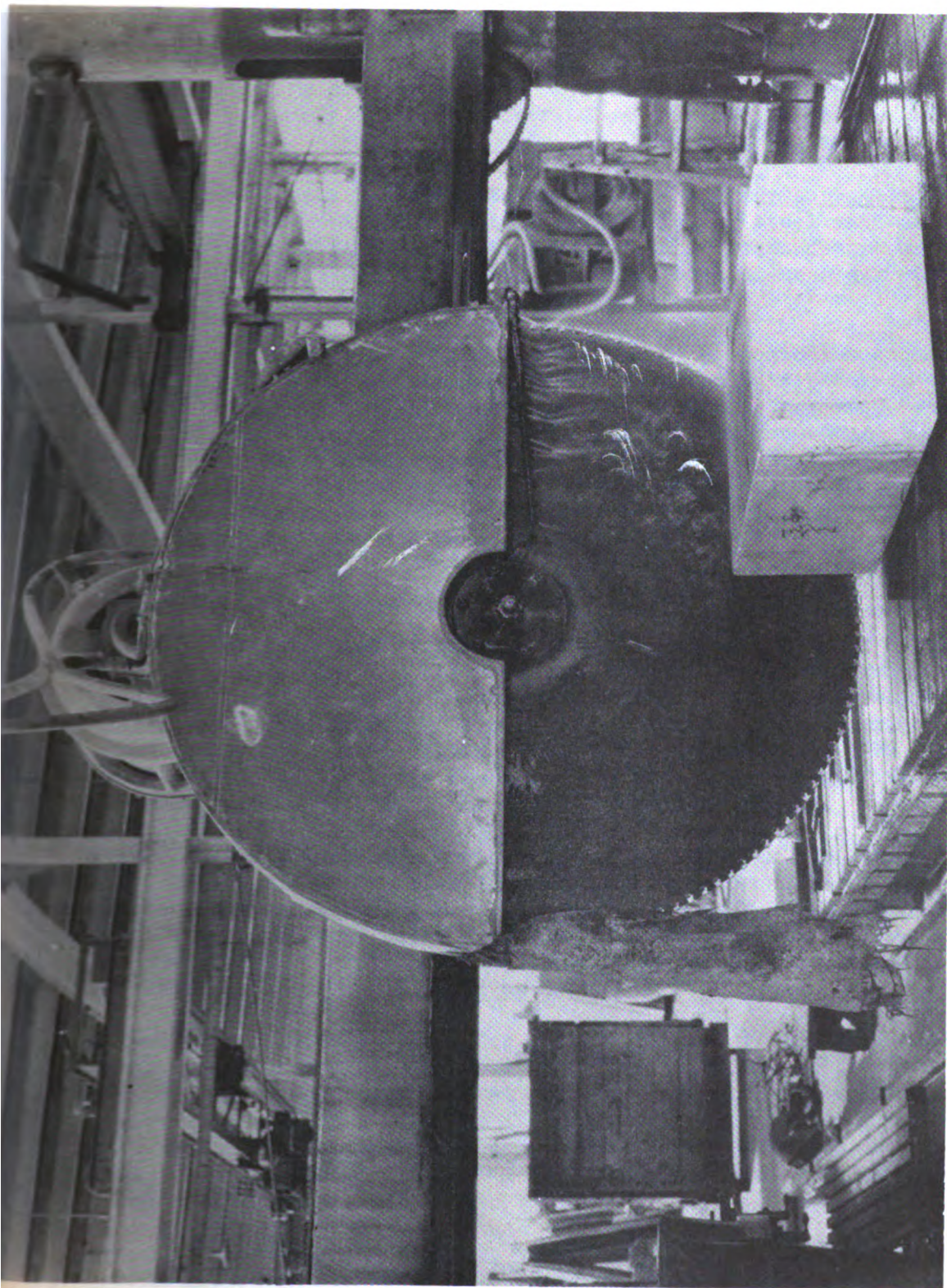


Figure 8.— Gang saws cutting marble. (Patch-Wegner type.)



Gritting produces what is known as a "hone" finish and is generally done in two stages with grits of different sizes. "Buffing," the process that gives a fine polish to the marble surface, is done with wet "putty powder" (commonly tin oxide) carried on a revolving felt buffer head.

Recutting of blocks and slabs to specified shape may be done with circular diamond saws, perforated-steel saws employing steel shot as abrasive, or with a straight blade in a gang frame. Diamond saws are used most widely. Moldings and cornices are cut with planers and with revolving forms of carborundum.

The wire saw is considered to be a useful and economical machine for stone or marble plants. The Wegner type required 3 to 5 horsepower, and the feed is automatic. All wire sheaves have double grooves, permitting use of the second groove when one is worn. Sheave-wheel bearings are provided with large grease cups. Marble blocks can be sawed at a rate of 1 inch to 6 inches per hour and limestone up to 30 inches. These saws are built to cut blocks up to 7 feet in height and 18 feet in length. Intricate cuts are handled easily.

Cutting and Finishing Slate

Slate for certain uses requires a high finish, according to Behre (cited). The relatively high cost of slate per unit is due largely to this need for finishing before marketing. Blocks of slate are reduced to workable sizes with iron circular saws 2 to 4 feet in diameter, $\frac{3}{8}$ inch in thickness, and revolving about 5 times per minute. No abrasive is used. Later, large slabs are cut accurately to specified dimensions by rapidly rotating, thin, silicon carbide wheels.

Henry Disston & Sons make an inserted-tooth circular saw for cutting slate. These are similar to saws used in a log mill but are much heavier, the teeth having a kerf of about $\frac{3}{4}$ inch. The teeth are of special steel, but many users desire a tooth tipped with borium, and the firm has experimented with teeth tipped with carboloy or tungsten carbide, which is of almost diamond hardness.

In American practice, blocks for structural use are finished with planers that have already been described. For finishing slabs for blackboards or for certain structural purposes, the cleavage surface is smoothed with sand on a rotating iron rubbing bed; by a mechanically moving abrading head; or by hand honing. Slate may be drilled for screw holes and the pieces fitted together into such equipment as tubs, basins, and switchboards.

After being sawed, the surfaces are finished on a planer whose bed travels back and forth similarly to the saw bed. When one side is finished the block is turned over, and the opposite side is planed. If de-

sired, a smoother surface is prepared on the rubbing bed, as is used in marble and sandstone finishing. Blackboards and switchboards are smoothed further by means of a carborundum cloth belt, a buffer, or other machine.

Cutting and Finishing Soapstone

Soapstone is a term applied to dark gray to greenish talcose (10 to 80 percent talc) massive rocks. Milling processes are similar to those for marble, according to Bowles (cited). Slab surfaces are smoothed on rubbing beds and are tongued and grooved with carborundum machines before being assembled as laundry tubs, sinks, acid tanks, aquariums, and similar products. An important branch of the industry is the manufacture of furnace blocks to line retorts in paper mills. Soapstone is used extensively in building construction for wainscoting, sills, caps, and spandrels. The harder varieties are used for floor tile and stair treads.

The drum rubber.— Figure 10 shows a "drum rubber." For marble, slate, soapstone, and limestone, the Norton Co. states that such grinding wheels are rapidly replacing rubbing beds in reducing slabs to exact dimensions and for removing irregularities left by gang saws. These drum rubbers usually are of silicon carbide, with a vitrified bond.

When coping marble, slate, soapstone, or limestone, heavy feeds and slow traversing cuts prevail — 6 inches deep and 60 feet per minute. Wheel peripheral speeds range from 5,000 to 7,500 surface feet per minute. The Norton wheels have steel centers and a rim of 1 to 3 inches of abrasive (usually silicon carbide) on the periphery. A copious supply of water is essential.

For some surfacing, such a machine is suitable. Silicon carbide is used on the wheels, different grain sizes and wheel speeds being employed for roughing, semifinish, and honing. Machines commonly used are Chicago Pneumatic Tool, Concrete Surfacing Machinery, Ingersoll-Rand, and Roto Air Tool maker.

Cutting and Finishing Sandstone

Gang saws similar to those used in granite and limestone mills generally are employed. Gangs with 10 to 15 blades saw average sandstone blocks 5 to 7 feet in length at a rate of 3 to 8 inches per hour when sand is used as abrasive and 6 to 12 inches when steel shot is used. Subsequent sawing of slabs may be done with silicon carbide circular saws or with blades mounted with diamond teeth and set in straight-cut gang frames. Diamond circular saws have not proved satisfactory for sawing sandstone, but those of silicon carbide are suitable. Wire saws are used in some places for jointing sandstone blocks.

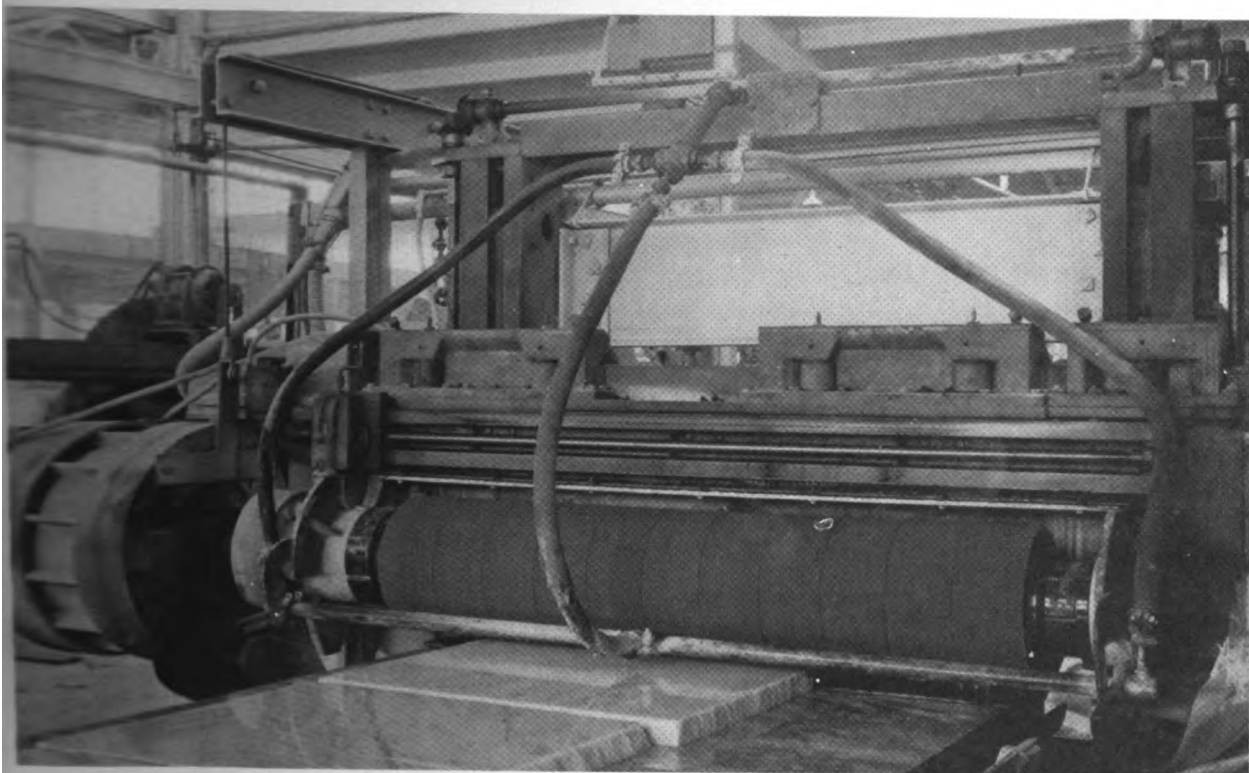


Figure 10.— A drum rubber polishing marble. (Courtesy Norton Co.)

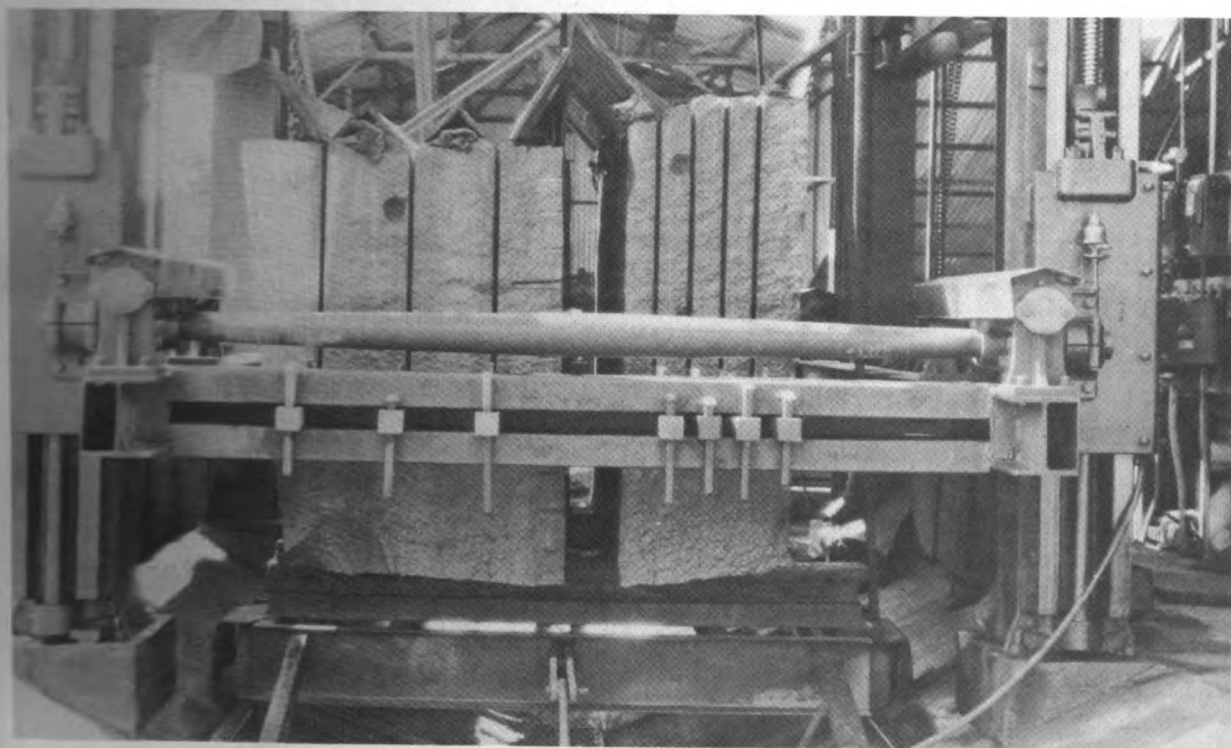


Figure 11.— Gang saw cutting granite. (Patch-Wegner type.)

Moldings are cut with planers, usually of the reversible-head type that cut in both directions. For hard sandstones a stream of water must be directed onto the cutting edge to prevent "burning" of the tool.

Cutting and Finishing Granite

During recent years, sawing has become an established process in granite mills. The gang saw consists of a series of steel blades set in parallel position in a frame that has a reciprocating motion. Spacing of the blades determines the thickness of the slab or block. Blades that are about 1/2 inch thick and have notches about 1 foot apart on the lower edge are fed with steel-shot abrasive. Garnet or carborundum also is used. The cutting rate ranges from 4 to 9 inches per hour.

Figure 11 shows a Patch-Wegner gang saw cutting granite. The rate depends on the number of blades and type of granite. The gang with direct motor drive and automatic pump feed is said to reduce considerably the cost per saved foot. Figure 8 shows a battery of Patch-Wegner saws that have a swing motion instead of a straight-cut or parallel motion. This type is used on soft stone or marble and may have as many as 50 to 100 blades at one time.

Circular saws 5 to 12 feet in diameter and provided with detachable notched-steel teeth also are employed in cutting granite. The granite blocks are mounted end to end on cars, and the spaces between are filled with plaster to keep the steel shot in the cut as the saw passes from one block to another. The rate of travel ranges from 1-1/4 to 5 inches per minute, and the saws cut 25 to 100 square feet per hour. Sawing is costly, but it conserves stone and, as cuts can be made in any direction irrespective of rift (line along which stone may split) or grain, the most attractive colors and patterns may be obtained. Also, the surfaces are so smooth that rubbing and polishing are facilitated greatly.

Much memorial and ornamental building granite is polished. Blocks pass through several successive stages of manufacture before a polished surface is obtained. Sawed blocks or those smoothed with surfacing machines are set in groups with their upper surfaces on an even plane. They are boxed in and all cracks filled with plaster. A power-driven rotary head known as a scroll, consisting of iron rings or segments, is supplied with steel shot and when guided over the surface wears it smooth. This process is known as ironing. The next step is to use a lighter scroll with loose silicon carbide or emery as abrasive. Finer and finer grades are used in succession. This process is known as emerying. The final stage, known as buffing, consists in polishing the surface with revolving pads of paper-mill felt supplied with "putty powder" - precipitated tin oxide. Single blocks are now polished in some mills without being set in plaster. The abrasive is collected in a trough for reuse. Small, air-driven, portable polishers are used for narrow edges, and curved or irregular surfaces are polished by hand.

Figure 12, supplies by the Norton Co., shows a coping wheel of silicon carbide cutting a slab of polished granite. Peripheral speeds range from 5,000 to 9,000 feet per minute.

Figure 13 shows a portable grinder at work on the edge of a stone.

Several makes of machines for polishing granite and other stones are available. Briefly, they consist of a standard with a movable arm, on which are a motor and a vertical, hollow (for water) spindle that carries emery rings, scroll wheels, star heads, and felt buffers as the work proceeds. These polishing adjuncts are moved by the operator, and the machine has a reach of several feet. Figure 14 shows granite being polished by a large machine.

Cutting and Finishing Miscellaneous Stones

Basalt, gabbro, and other basic igneous rocks are used to some extent for building and monumental purposes. Tuffs, pumice, and other porous volcanic rocks are used sparingly as lightweight building material. Mica schists are used as abrasive stones, for lining kilns and furnaces, and also for building purposes. Diatomite, tripoli, and pumice are shaped into refractory or filter blocks. All of these rocks are sawed and cut by the methods described, according to hardness and purpose.

For cutting small stones and bricks for special fitting on a construction job, portable circular saws with bench are made by the Norton Co. and other firms, just as portable wood saws are used at a building. Such operation is easier and is more accurate and rapid than hand work. Saw wheels commonly used for cutting stones—granite, limestone, marble, tile, vitrified clay tile, and terra cotta—are of silicon carbide, 6 to 16 inches in diameter and $3/32$ to $1/8$ inch in thickness, and run at high speed.

One firm makes two sizes of motor-driven stone saws for cutting limestone, ashlar, sandstone, slate, marble, roofing tile, asbestos roofing, transite panels, and other rocklike materials. The 9- and 12-inch abrasive wheels travel at 2,500 and 2,100 revolutions per minute and leave a clean job. These saws will also cut metal if required. They weigh 31 and 39 pounds complete. The material to be cut is laid on a bench and the hand-held saw is pressed against it.

EXAMINATION OF MINERAL SPECIMENS

In the Bureau of Mines

The Bureau of Mines receives many pieces of rock (sometimes specimens and sometimes representative samples) for examination. A cursory determination or simple test is made, but if a rock received at the Eastern Experiment Station, College Park, Md., is of particular interest, it may be cut by sawing and polished to obtain further information as to

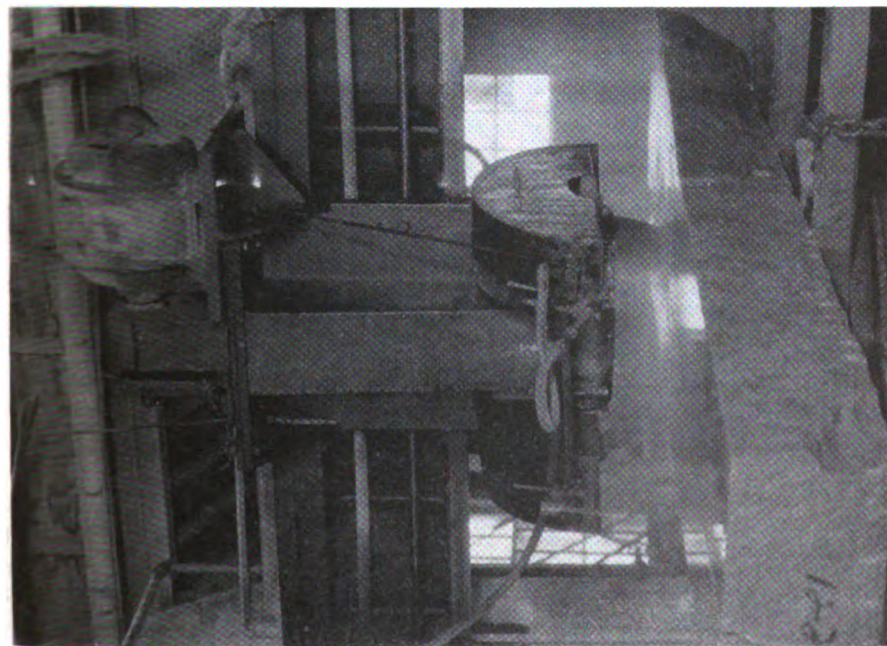


Figure 12.— Wheel of Crystolon cutting a
slab of polished granite. (Courtesy
Norton Co.)

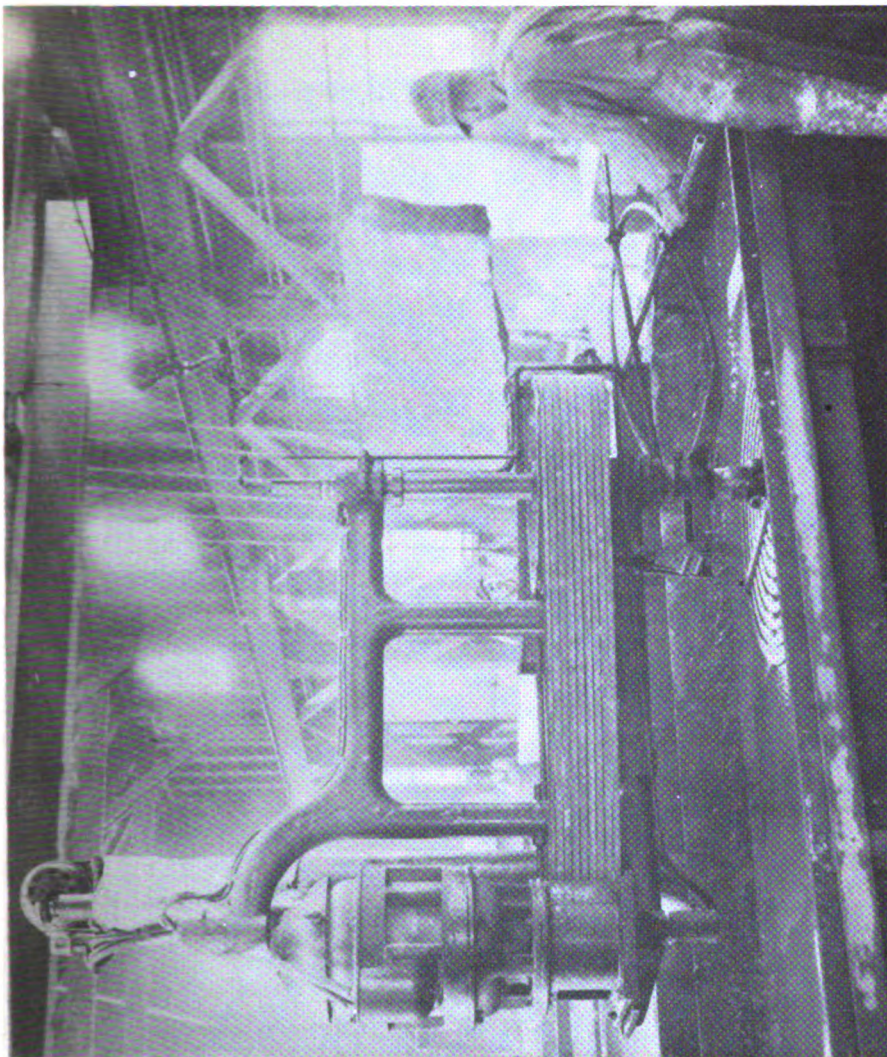


Figure 14.— Patch-Wegner machine polishing granite



**Figure 13.— A portable grinder at work.
(Courtesy Norton Co.)**

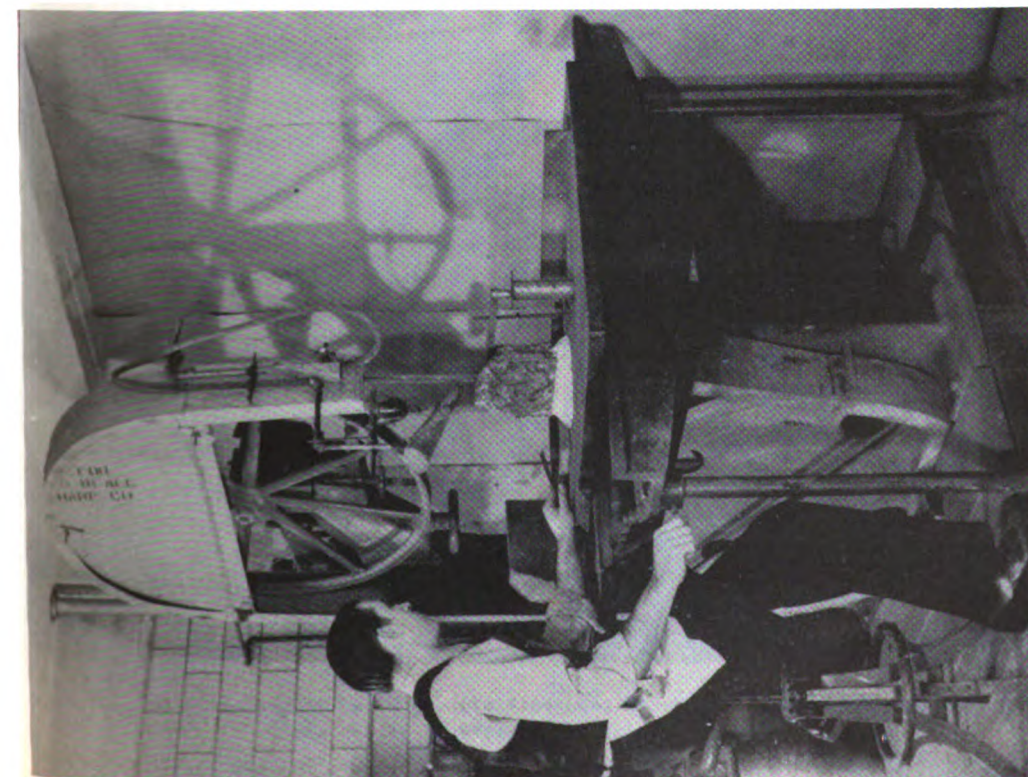


Figure 15.— Band saw cutting rock set in plaster
of Paris, as described.

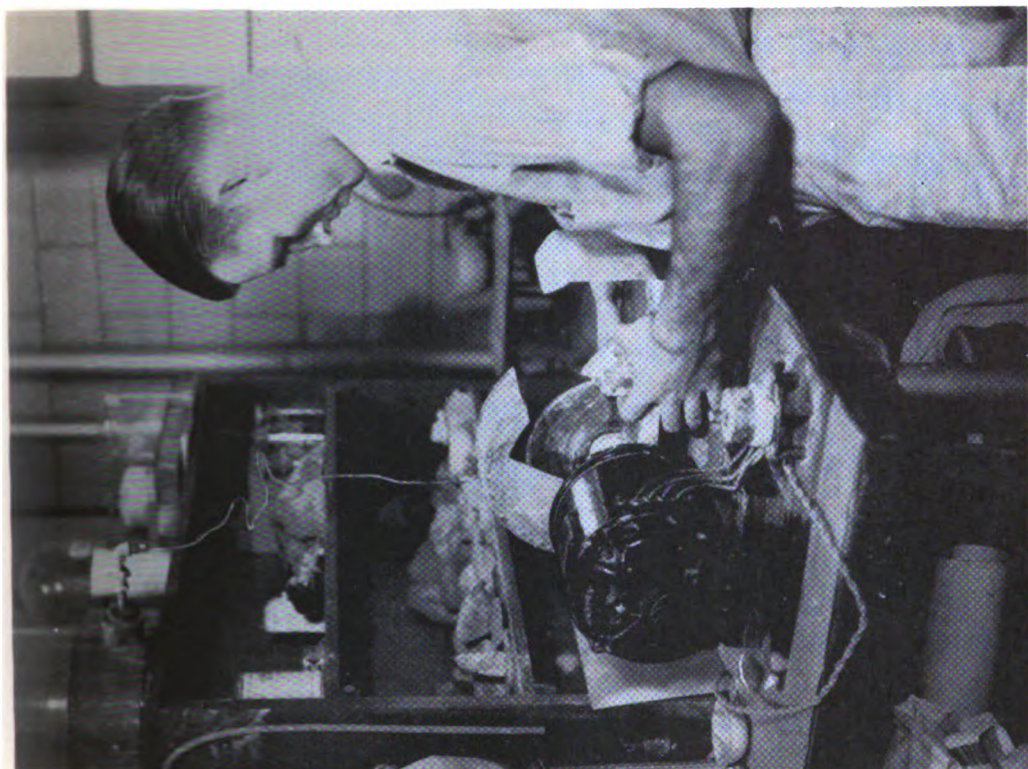


Figure 16.— Diamond saw for cutting small specimens.



Figure 17.— Laps for grinding and polishing stones. That being used is a felt buff for finishing; the others are for grinding off the roughness after cutting.

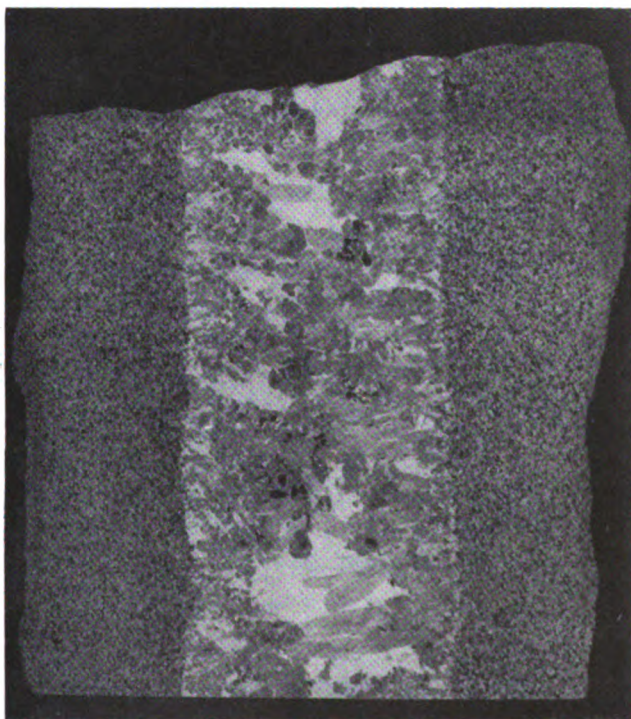


Figure 18.— Spodumene pegmatite in granite from Long Creek, near Kings Mountain, N. C.: A, In the rough; B, after grinding and polishing.

its make-up or constitution. Rocks of 1 pound or more, up to several hundred pounds, are handled by the equipment shown in figure 15. This is in charge of the principal mineralogist and an assistant, L. F. Vanover. The Optical Section, which has a microscope, a spectroscope, X-ray apparatus, and camera operated by Alton Gabriel, Morris Slavin, and Howard Carl, assists in identification of minerals when necessary.

Large stones are cut with a band saw. This consists of a 21-foot endless piece of steel, 1-1/4 inches wide and 1/16 inch or more thick which travels around two 42-inch wheels at about 2,200 surface feet per minute; and the specimen to be cut, when firmly clamped down, is pressed against the saw by means of a screw-feed table. No. 120 silicon carbide is fed to the edge of the saw with a small stream of water. About 1 pound of abrasive per hour is used. The life of the band varies according to the type of rock being cut.

If the rock to be cut has rough sides, one side may be set in some plaster; and in order that the stream of abrasive may flow directly to the saw, a channel is made on the rock with modeler's clay. The clay and plaster can be removed easily, and the cut specimen is washed for inspection.

The proof of good cutting with a band saw is a flat surface; a wavy cut denotes too much feed or pressure against the saw. Slabs of meteorite cut in the National Museum are of even thickness, as would be shown by a gage. Uneven cutting involves unnecessary grinding on the laps.

Small stones are cut by a copper-diamond blade (figs. 16 and 23). These wheels may last a day or several weeks.

If the faces of the pieces cut are to be polished, they are first ground with No. 120 silicon carbide and water on a steel lap. This operation requires some skill in holding the specimen down and moving it around against the rotation of the lap and adding fresh abrasive. Saw cuts soon are smoothed off, and the piece is washed for inspection. It is then given a smoother finish and made ready for polishing by grinding on another lap with No. 600 silicon carbide. Much care must be taken to wash the specimen clear and otherwise prevent any of the coarser abrasive from getting on the finishing lap and scratching the stone. If satisfactory, the piece is then polished on the felt lap with pre-digested tin oxide as an abrasive. Figure 17 shows the finishing laps and figure 18 shows a stone before and after grinding and polishing.

In the Geological Survey

Three main types of work are involved in the preparation of rocks, minerals, and ores for study in the Petrographic Laboratory of the Geological Survey, Interior Building North, Washington, D. C., in charge of C. S. Ross and Frank S. Reed, who gave the authors the following information:

Thin sections of rocks or minerals are used for examination under the microscope by means of transmitted light. This preparation of thin sections in the laboratory involves such diverse materials as igneous rocks and sedimentary rocks, including clays, shales, and poorly cemented sands, coal, and oil shales. Each requires somewhat different treatment, and no general rules for the preparation of the more difficult materials are possible. However, the methods for making thin sections of firm igneous and sedimentary rocks are fairly well standardized.

Most commonly a small chip or a rock slice cut with a diamond saw is selected, and is ground flat on one side. The grinding is done on a revolving, soft-steel plate and with successively finer carborundum - 120 for coarse, 1F for intermediate, and 600 for final grinding. The steel plates are direct-connected to a vertical 1.5-horsepower motor and run at a speed of 1,150 revolutions per minute.

After fine grinding, but without polishing, the smooth side of the chip is cemented to a glass with carefully cooked Canada balsam. It is then ground on the opposite side with carborundum. It is necessary to reduce the film of rock to a thickness of about 0.03 millimeter or about 1/1,000 inch. This operation requires skill to prevent breaking away of the film and to keep a uniform thickness over the entire area, also judgment as to when the proper thickness has been attained by examining the selection from time to time under the microscope. All quartz and feldspar should be gray under crossed nicols when the proper thickness has been attained. With some types of material, a final grinding by hand on a glass plate with an optical grade of emery is advisable, but for most materials a skilled worker can complete the grinding on the steel lap. The advisable size of a section depends on the texture of the rock, as a coarse-grained rock may require a large thin section, but a finished section about 3/4 inch square is a standard size.

When grinding is finished, the excess balsam around edges of the section is washed away with turpentine and a fine camel-hair brush and then dried. The slide is placed on a mounting table and a coating of balsam (tubed) placed on the section. When it has been heated sufficiently on the mounting table so that the balsam is hard when cooled, a cover glass is cemented on. Balsam should not be too hard but of such consistency that it can be

pressed in by the thumb nail. The surplus balsam around the cover glass is cut away with hot knives, and the slide is then washed in alcohol and water.

Sections of oil shales and coal are difficult to make because they are so easily broken down by heat and because extreme thinness is required to permit so dense a material to transmit light.

Clays, shales, and friable rocks require special treatment - impregnation and hardening with balsam or bakelite before sectioning.

Metallic minerals are polished highly so that they can be studied by reflected light under a microscope. This requires a specimen about $3/4$ inch square. After the preliminary grinding with coarse (120) and fine (600) carborundum the specimen is given its first polish on 6-inch cloth-covered lap, and for this 600 alundum is used. It gives a rough polish, and final polishing is done on another lap covered with samson cloth (billiards cloth). Magnesium oxide is used for this polishing, which continues until pits and scratches are not visible under the microscope. It is also necessary that the hard and soft minerals be polished equally and that the hard minerals show a minimum of relief. This requires extreme care in technique, and the method must be varied to suit each set of conditions.

Some studies, especially those of the mineral relations in coarse-grained rocks, require that hand specimens, some as much as a foot in diameter, be polished. Smaller specimens are sawed with a circular diamond saw 8 inches in diameter, and the larger ones with a band saw. For this purpose a band saw similar to that of the Bureau of Mines is used, travelling at about 1,500 feet per minute. Carborundum 120 is fed against the saw blade, together with water, drop by drop; more water tends to wash the carborundum away, producing waste and slow cutting. After being sawed, the specimens are ground on steel laps using successively finer grades of carborundum, as in making sections. The specimen is finally polished on a lap covered with "Spanish felt" 1 inch thick, with tin oxide as the polishing medium.

In the Bureau of Mines and Geological Survey, as well as in many professional, college, and mine and metallurgical laboratories, thin sections (0.02 to 0.04 millimeter in thickness, corresponding to 400 to 325 mesh) of rocks are prepared for microscopic determination of the constituent minerals. Petrographic analysis is suitable for transparent minerals and mineragraphic analysis for opaque minerals. Much

has been written on the two methods - Head^{7/} and Thiessen^{8/} of the Bureau of Mines and Short^{9/} of the Geological Survey, for instance.

Short states that the metallographic microscope is the most valuable instrument for identifying opaque minerals and for studying their mutual relationships.

In the National Museum

The Division of Mineralogy, National Museum, Washington, D. C., receives many specimens for examination and for exhibit. Some of the latter class are of great size and value. The cutting and grinding laboratory is under the supervision of B. O. Reberholt and contains a regular band saw 1 1/4 inches wide on two 36-inch wheels that make 100 revolutions per minute, as shown in figure 19. No. 100 carborundum powder is used. Great care is taken to prevent an uneven cut, and in no cutting is the band forced into a specimen. End views of a slab or slice of a meteorite (90 percent or more iron and high in nickel) or of a cut of log of petrified wood show straight sawing. Figure 20 is a view of a cut, polished, and etched slab of a meteorite showing Widmanstätten figures. Mehl's interesting paper^{10/}, "Iron from Heaven," may be read with profit in this connection. Some man-made iron alloys have similar markings.

To the left in figure 19 is a grinding and polishing machine for large cut pieces. Three cast-iron wheels of different diameters are attached, one at a time, and run at 150 revolutions per minute. Three sizes of abrasive are used. The grinding wheels in motion are moved across the stones by means of a loop handle. As this machine is used only for big stones, others are ground and polished with powders on laps rotating 150 to 300 times a minute. The large laps are 28 inches and the smaller ones 16 inches in diameter.

Thin sections for microscopic examination also are made in this laboratory.

-
- ^{7/} Head, R. E., The Technique of Preparing Thin Sections of Rock: Bureau of Mines and Univ. of Utah Coop. Tech. Paper 8, 1929, 29 pp.
Head, R. E., and Slavin, M., A New Development in the Preparation of Briquetted Mineral Grains: Bureau of Mines and Univ. of Utah Coop. Tech. Paper 10, 1930, 11 pp.
 - ^{8/} Thiessen, R., Sprunk, G. C., and O'Donnell, H. J., Preparation of Thin Sections of Coal: Bureau of Mines Inf. Circ. 7021, 1938, 8 pp.
 - ^{9/} Short, M. N., Microscopic Determination of the Ore Minerals: Geol. Survey Bull. 825, 1931, 204 pp. Being revised and reprinted as Bull. 914.
 - ^{10/} Mehl, Robert F., Iron from Heaven: Carnegie Mag., vol. 11, January 1938, 6 pp.

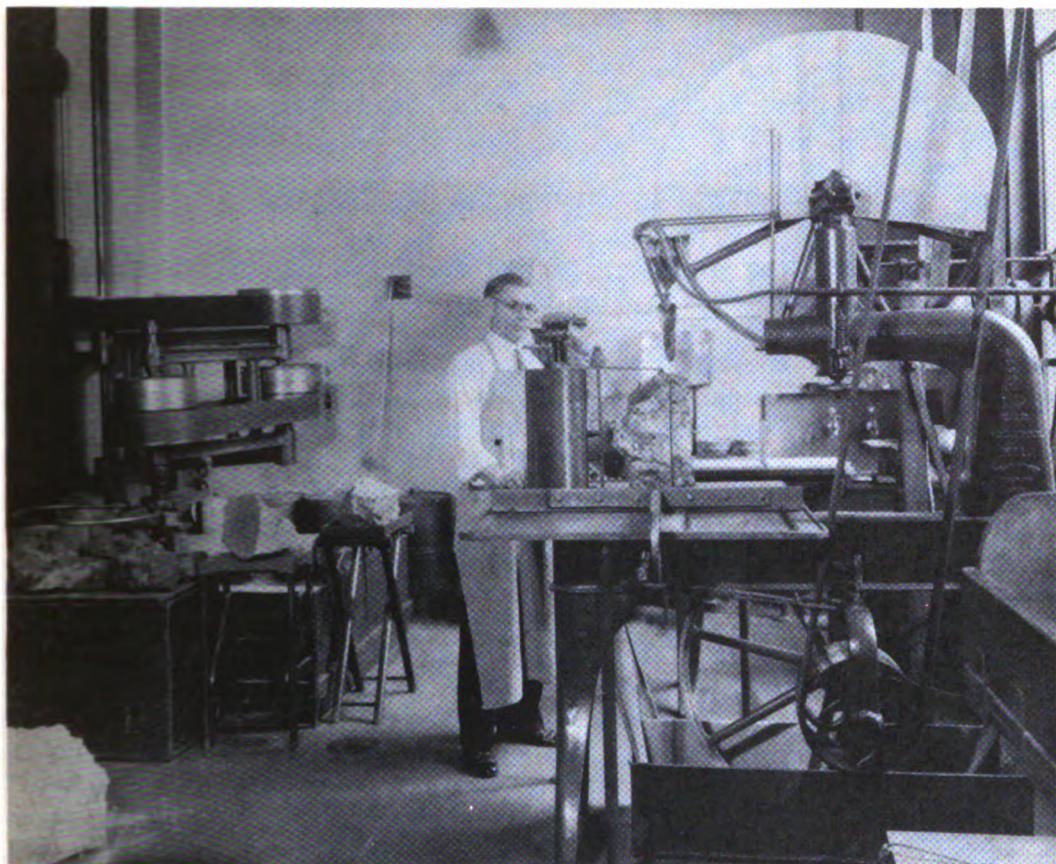


Figure 19.— Band saw and polishing machine in geological laboratory, United States National Museum. Note the saw cut in stone on feed table.

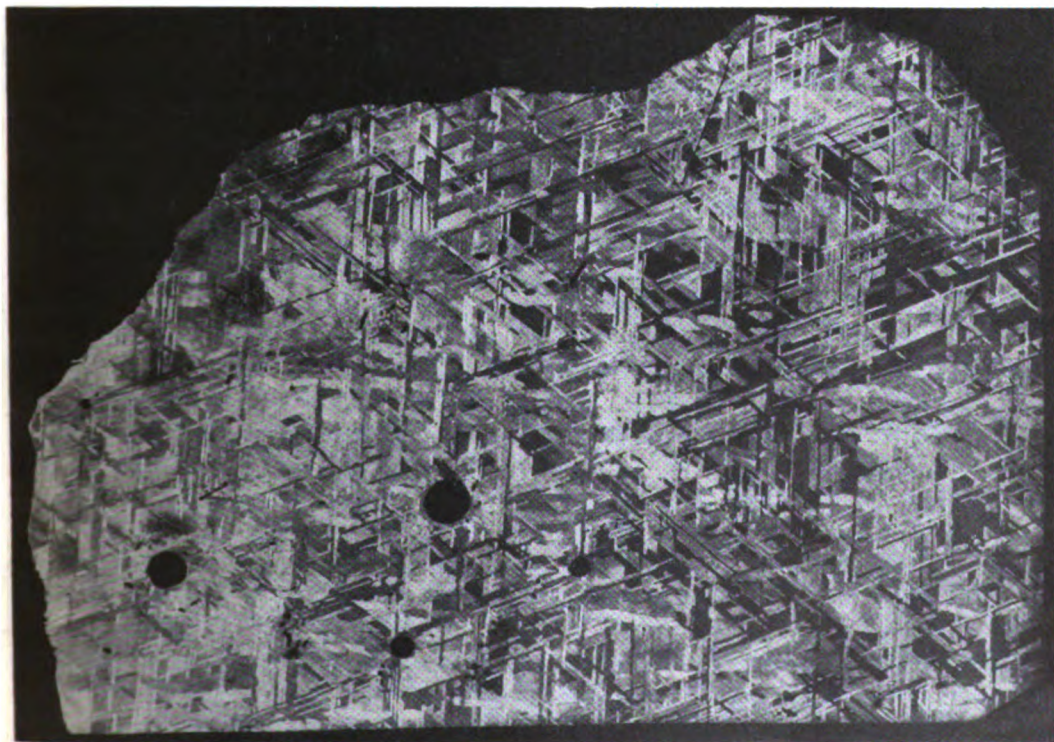


Figure 20.— Face of cut and etched meteorite showing Widmanstätten figures. (Specimen in United States National Museum.)

Reberholt^{11/} has described this shop and gives some practical hints on cutting and polishing.

CUTTING AND POLISHING GEM STONES

As there are good and recent textbooks^{12/} on gem cutting, this part is confined mainly to the operations connected with quartz minerals.

Ball's annual review^{13/} of gem stones in the United States is generally informative as to their production and handling. There is a continuous demand for California kunzite and tourmaline and Nevada turquoise. In the Pacific Northwest, particularly in Oregon, are many collectors and amateur lapidaries who cut agate and other quartz minerals, and others who send their "finds" to professional lapidaries. Rose quartz, agatized wood, amazon stone, amethyst, and smoky quartz also are mined.

The 46 pages that comprise part III of Baxter's book, "The Art of Gem-Stone Cutting," contains practical information, because the author is instructor in art metal and jewelry in the Woodrow Wilson High School, Washington, D. C. Clear photographs show gemcutting shops, close-ups of grinding and polishing wheels, the mounting of specimens, and facet cutting, all with suitable explanations of the operations and abrasives used.

Kraus and Slawson's chapter VII, of 43 pages, "Cutting and Polishing Gems," treats the subject somewhat more technically, especially as to types of cuts, which are accurately sketched. Pictures of cutters at work add to the instructive value of the text.

- 11/ Reberholt, B. O., Preparation of Rocks and Minerals for Study and Exhibition: Rocks and Minerals, vol. 10, April 1935, pp. 53-55.
- 12/ Howard, J. H., Handbook for the Amateur Lapidary: 1935, 150 pp., \$2. (Obtainable from the author, 504 Crescent Avenue, Greenville, S. C.)
Dake, H. C., Fleener, F. L., and Wilson, B. H., The Quartz Family Minerals - A handbook for the mineral collector: McGraw-Hill Book Co., New York, 1938, 304 pp., \$2.50.
Kraus, E. H., and Slawson, C. B., Gems and Gem Materials: McGraw-Hill Book Co., New York, 3d ed., 1939, 237 pp., \$3.50
Baxter, W. T., with Dake, H. C., Jewelry, Gem Cutting, and Metalcraft: McGraw-Hill Book Co., New York, 1938, pp. 133-178, \$2.50. (Preceding the index are three pages listing dealers in gem-cutting and polishing equipment.)
Kraus, E. H., Hunt, W. F., and Ramsdell, L. S., Mineralogy: An Introduction to the Study of Minerals and Crystals: McGraw-Hill Book Co., New York, 1936, 638 pp.
- 13/ Ball, Sydney H., Gem Stones: Bureau of Mines Minerals Yearbook, 1939, pp. 1385-1396.

Equipment Used

The sequence of operations in lapidary work is sawing large rough stones with a fast-running saw or blade and abrasives, grinding with an abrasive wheel, sanding to remove grinding marks with a wood or iron disk on which is abrasive paper or cloth, polishing with abrasives on a metal lap, and finishing on a felt buff or lap.

For gem-cutting, the Carborundum Co. has a lapidary abrasive kit. This is inexpensive (\$5.50 net, plus postage) and includes two silicon carbide wheels and four sets of bushings, four silicon carbide cloth disks, five cans of silicon carbide grain or grit of different sizes, and three cans of silicon carbide buffing powders. These items cover the requirements of the amateur gem cutter from start to finish, excepting the motor and spindle or shafting.

For safe operation and to prevent splashing, all disks and wheels should be shielded by sheet metal, which covers half to two-thirds of the wheels. Also, such protection prevents waste of the abrasive medium.

Saws

Diamond saw.— If a stone or fragment is too big or too irregular for shaping on a grinding wheel, it may be sawed by a mud saw or by a diamond saw. The former may consist of a disk of 20-gage steel running at 250 to 350 revolutions per minute through a mixture of mud made up of No. 120 silicon carbide, water, and clay or ordinary flour. The stone is held firmly against the revolving disk, and the shapes desired are cut. Figure 21 shows a Felker Di-Met machine whose blade or wheel is diamond-impregnated. No clamps or special mountings are needed, and a rock may be held in the hand or supported with modeling clay. Cutting is done quickly and accurately. The blades are 6 and 8 inches in diameter and have a vertical adjustment of 5-1/2 inches, and the guard prevents undue splattering. Drain-holes dispose of the waste. The table has a 10-1/2 inch travel. Figure 22 shows a saw cutting a piece of quartz and slate.

For a variety of stones, J. K. Smit & Sons make 6-, 8-, and 10-inch blades of the type shown in figure 23. The respective thickness of the cutting edge is 0.04, 0.05, and 0.062 inch. The saws are impregnated with crushed bortz and are durable. Originally they were intended for cutting glazed tile and brick, terra cotta, and other building materials, but they are satisfactory on fused silica, petrified wood, marble, granite, limestone, semiprecious stones, and other stones. This type of blade (copper) is run in the laboratory at College Park. It travels at 1,750 revolutions per minute. Its life is 1 day to several weeks, depending on the hardness and quantity of the stones cut.

The diamond saw is also to be seen in gem-cutting establishments. Its metal and speed are similar to those of the mud saw, but the disk

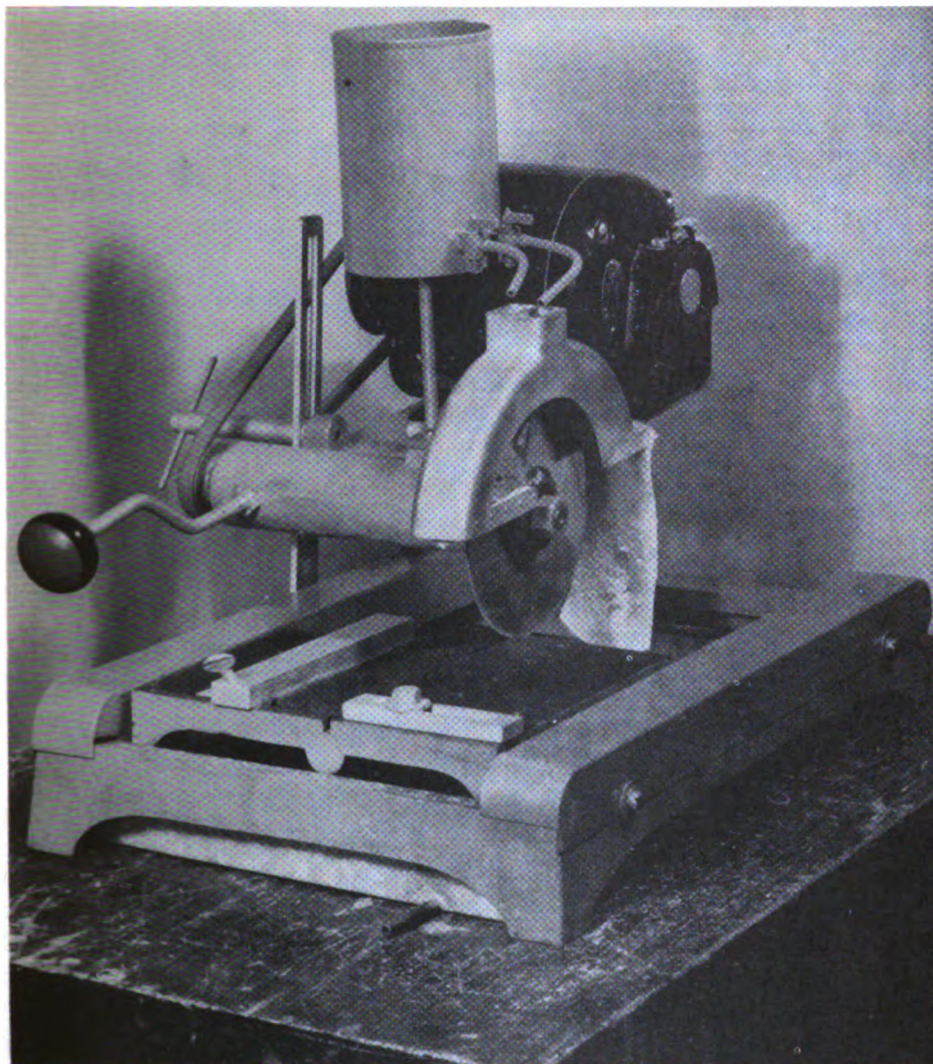


Figure 21.- A compact rock-cutting machine. (Felker Di-Met type.)



Figure 22.- A diamond saw in action. (Felker Di-Met type.)

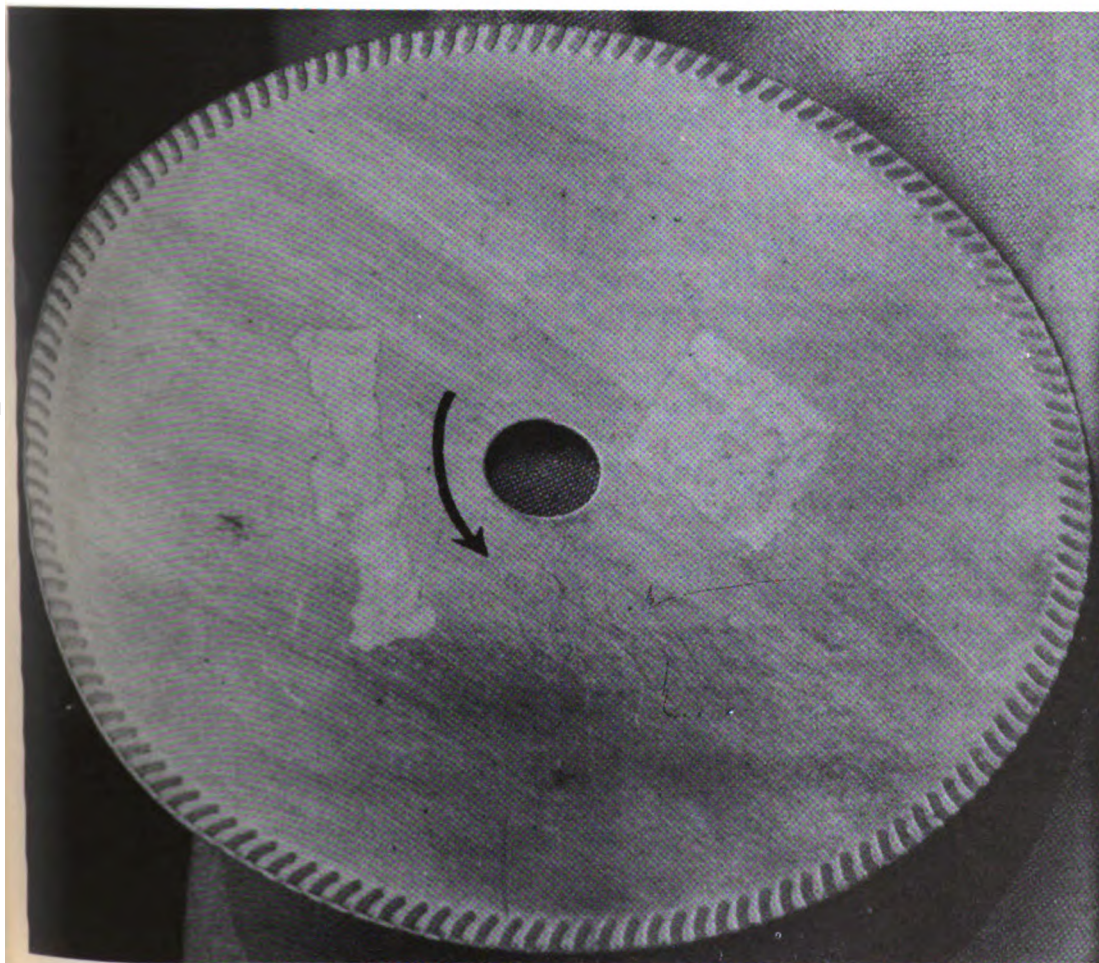


Figure 23.— A diamond-impregnated blade suitable for semiprecious stones.

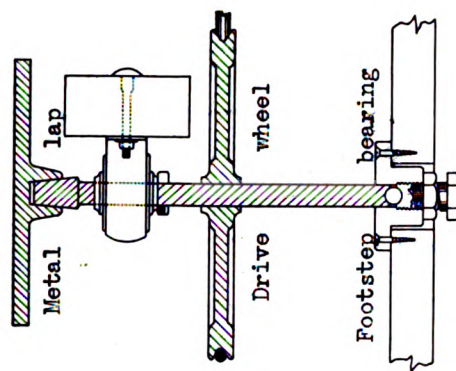


Figure 24.— Vertical section of a simple lap. The pan in which the lap runs is not shown.

periphery is notched to a depth of $1/32$ inch at $1/16$ -inch spaces. Powdered (100-mesh) diamond bortz (industrial stones from $1/2$ carat to 2 carats) is mixed with vaseline and applied to the notches with a toothpick and then rubbed into them with the fingertips. The notches are then closed tight by means of a light peen hammer, also by holding a hard steel roller against the rotating disk. When in operation, the diamond saw is kept lubricated by running the edge in a mixture of equal parts of kerosene and motor oil.

For such stones as agate and petrified wood (hardness 7) Carborundum-brand diamond blades are reported to be used widely. The blade consists of a high-quality copper disk impregnated around the periphery with a coating of carefully graded diamond chips. Like all diamond saws they must have a plentiful supply of water and when worked under proper conditions are quite efficient.

Laps

A lap is a piece of metal, wood, leather, or other material, usually in the form of a disk revolving rapidly on a vertical axis. It holds a wetted abrasive powder on its surface for cutting and polishing stones and gems, which are held on the surface by hand or pressure mechanically. Figure 24 is a vertical section of a simple lap taken from "Norton Abrasives for the Lapidary" (1939), and figure 17 shows the two cast-iron polishing laps and the felt finishing lap in the Eastern Experiment Station of the Bureau of Mines, College Park, Md. They travel at 255 revolutions per minute and are direct-driven instead of by belt. The sketch (fig. 24) shows a lap that can be used in facet cutting or for finishing large flat surfaces. Only one master lap of cast iron is required. The working surface is provided by a 16-gage metal disk, which is easily mounted or removed, thus allowing a lapidary to have a separate lap for every grit size and kind of abrasive used.

Laps may be of iron, bronze, copper, tin, pewter, lead, or any other metal; but in general, the softer the gem stone, the softer should be the metal lap. Minerals having a hardness of 7 or less may be polished at a speed of 100 revolutions per minute, but 300 revolutions should be employed for those of 8 or harder. The abrasive is made up with water to a mud or creamy paste.

A number of polishing machines are available, some of them compact. For example, the firm of A. I. Buehler, Chicago, makes a vertical lap occupying small space on a bench, and the thrust-ball-bearing motor runs at 575 to 1,150 revolutions per minute. A slow-speed polisher operates at 250 revolutions and is direct-driven by a motor on one side.

Quartz Minerals

According to Dake, Fleener, and Wilson (cited), the modern method of cutting and polishing quartz (hardness 7) into gem stones is essentially

similar to the technique applied to other semiprecious stones of similar hardness. The amateur method employs simple and inexpensive equipment; the industrial methods involve rather elaborate and costly machinery.

Hardness and Abrasives

The hardness of gems ranges from 7 to 9, according to Juergens.^{14/} For example, the quartz group (amethyst, chalcedony, and crystal) is 7 on the hardness scale; the beryl, garnet, tourmaline, and zircon groups (aquamarine and emerald, garnet, tourmaline, and zircons), around 7-1/2; topaz, 8; and the corundum group (ruby and sapphire), 9. The diamond is 10. This being so, an abrasive such as silicon carbide and aluminum oxide, which have a hardness of up to 9-1/2, must be used for polishing gem stones.

Grinding and Polishing

Grinding wheels are necessary for shaping quartz gems in other than flat surfaces with no re-entrant angles. Laps may be used on flat surfaces and facets, and either laps or wheels for removing the rough surface of a specimen before sanding and polishing. Most of the wheels are silicon carbide, the product of the electric furnace. Ordinarily, they are 12 inches in diameter and make 1,775 revolutions per minute. A small spray of water should be applied to the circumference of the wheel to prevent dust and keep it clean and cool. Two wheels are mounted - one of No. 100 grit for fast cutting and roughing out and one of No. 220 grit for final shaping.

Sanding is a dry operation employed to remove deep scratches and wheel marks on a stone. Silicon carbide-charged cloth (so-called emery cloth) of No. 220 grit is fastened over the side of a 2- by 8- or 10-inch wooden disk, with a felt pad to give a soft base underneath the cloth. the wheel makes 1,200 to 1,500 revolutions per minute. Large stones may be held against it by hand, and small stones are cemented to the end of a wooden stick and held thus. Scratches should be removed as much as possible before polishing.

As a rule, felt buffs are used to place the final high glossy polish on cabochon styles of quartz gems. Flat or rounded surfaces on stones can be polished by felt buffs. A wheel may be 1 inch by 6 inches run at 900 surface feet per minute. Artificial abrasives, tin oxide, tripoli, and other polishing powders are used.

HOW THE CHINESE CUT AND POLISH JADE

While in China during 1929, Frank L. Hess was permitted to visit the shops of several jade cutters and carvers. Although the working conditions were rather crude, the results were good.

^{14/} Juergens, H. Paul, Gems; A Classification According to Color: National Jeweler, Inc., Chicago, 1939, 59 pp.



Figure 25.— Students at work in jewelry and gem-cutting class at Woodrow Wilson High School, Washington, D. C. Students at left are grinding cabochons on silicon-carbide wheels. Those to right of sink are polishing the gem stones on felt wheels. Students grind their own gem stones and then fabricate the mountings from sterling silver, hard soldering (silver soldering) all joints. (Photograph courtesy of W. T. Baxter, instructor of class and author of Jewelry, Gem Cutting, and Metalcraft.)

In one place, a block of jade 12 by 12 by 5 inches was being sawed. The saw consisted of a length of 20-gage zinc-coated iron wire fastened to a bamboo bow 5 feet long. Spare wire was wrapped around one end of the bow. Carborundum of about 60-mesh was fed into the wire in the cut, which was straight, smooth, and narrow, equal to any cutting done by a mechanical band saw.

In another shop, circular pieces of jade were being cut from slabs such as those made in the first shop visited. Each of the six machines had a bench in two parts; and on each half, three circular pieces could be cut simultaneously. The slabs were laid flat, and a piece of tin plate 8 inches wide was wrapped around an upright wooden spindle of the size required. The tin plate lacked $5/8$ inch of completely surrounding the spindle, and was cemented thereto by a black gum, which was used as a bridge to stiffen the tin-plate cylinder. For bracelets, the center of the jade was cut out and a larger cutter was used to form the ring. The spindles were mounted vertically and given a forward and backward motion by treadles connected by a strap to a power spindle. A youth worked the treadles for three saws, and evidently the work was strenuous. Sixty-mesh carborundum was fed with water. About 3 hours was required for a cut through a slab $5/8$ inch thick.

In a third establishment, carving and polishing were under way. To saw small, thin pieces of jade, a circular, dished disk of thin, soft steel, shaped like a cereal dish with a flat, broad rim, hung vertically with the edge toward the workman, was used. By means of treadles and a strap wound around the spindle, the disk is run backward and forward. The "work" or piece of jade is held against the saw, and carborundum and water do the cutting. To grind pieces to shape, an 8-inch wheel with four spokes and a $3/4$ - by $3/4$ -inch rim is employed. It, also, is mounted on a horizontal spindle and is run by a strap and treadles, carborundum being used. After grinding, the pieces are carved on $1/2$ -inch-diameter leather wheels. Polishing is effected by an aqueous clay and water on small leather wheels.

SCHOOL INSTRUCTION IN CUTTING, POLISHING, AND MOUNTING GEM STONES

In charge of the metal-working and gem-cutting class of the Woodrow Wilson High School, Washington, D. C., is W. T. Baxter, author of one of the books listed in this circular. A class of 25 students (boys and girls) of the tenth, eleventh, and twelfth grades has a 2-hour period of instruction each week, there being a class of this period each day. A spacious room is well-equipped with work benches, a 10-inch diamond saw, which runs in fuel oil, grinding and polishing wheels (vertical laps), gas jets for blow-piping, and other accessories. (A 12-inch saw using silicon carbide and clay flour, and running at 300 revolutions per minute has since been installed for cutting stones.) Good-looking unset gems and gems set in silver rings and brooches are to be seen in finished and unfinished stages of cutting and polishing. Students are permitted to select from an album designs for mounting their finished gems. Figure 25, supplied by Mr. Baxter, shows a class busily at work, as seen by the authors.